Attachment 4
The Uinta Basin

The Uinta Coal Basin is located in eastern Utah and a very small part of northwestern Colorado (Figure A4-1). The basin covers an area of approximately 14,450 square miles (Quarterly Review, 1993) is structurally separated from the Piceance Basin by the Douglas Creek Arch (Figure A4-1), an up-warp near the state line between Utah and Colorado. Coalbeds are present within Cretaceous strata throughout much of the Uinta Basin. However, coalbed methane exploration, to date, has targeted coal beds in the Ferron Sandstone Member of the Mancos Shale and coal beds in the Blackhawk Formation of the Mesaverde Group. The total, in-place, coal bed gas resources in the Wasatch Plateau, Emory, Book Cliffs and Sago coal fields have been estimated at eight trillion cubic feet (TCF) to more than 10 TCF by the Utah Geological Survey (Gloyn and Sommer, 1993). This estimate is based on extrapolation of known coal resources to a depth of 9,000 feet and an average projected gas content of 330 cubic feet per ton and does not include the Tabby Mountain or Vernal coalfields, or the Sevier-Sanpete coal region. Total production stood at 75.7 billion cubic feet of coalbed methane in 2000 (GTI, 2002).

4.1 Basin Geology

Much of the Rocky Mountain region, including the Uinta Basin was covered by an epicontinental sea. Deposition in the sea lasted from the Albian (about 100 million years ago) through the Cenonmanian (about 83 million years ago), with the deposition of the upper part of the Mesaverde Group generally marking the end of marine deposition in the basin (Howells et al., 1987).

The Uinta Basin formed as a result of uplift and deformation that began in the Late Cretaceous. The Cretaceous sediments outcrop along the perimeter of the basin. The basin is asymmetrical in shape with strata on the northern flank of the basin dipping steeply toward the basin axis, while strata on the southern flank dip gently toward the basin axis. The stratigraphic units of the coal bearing Cretaceous rocks of the Uinta basin are shown in Figure A4-2.

Two Cretaceous stratigraphic units have been targeted for coalbed methane exploration: the Ferron Sandstone Member of the Mancos Shale and the Blackhawk Formation of the Mesaverde Group (Figure A4-2). The Ferron Sandstone Member was deposited in the Last Chance delta, a fluvial-deltaic environment (Garrison et al., 1997). The coal beds and interbedded sandstone units form a wedge of clastic sediment 150 to 750 feet thick stratigraphiclly above the Tunuck Shale Member of the Mancos Shale and below the Lower Blue Gate Shale Member of the Mancos Shale (Figure A4-2). Both of these shale units have a very low permeability and constitute confining units for water and gas in the Ferron Sandstone Member. The coal bearing rocks are thickest to the west and south margins of the basin, nearer to the upland sources of sediment. Coal mines producing from the Ferron Sandstone Member are located along the eastern boundary of the Wasatch Plateau south of Castle Dale, Utah (Figure A4-1). Depths to coal in the Ferron Sandstone Member range from 1,000 to over 7,000 feet (Garrison et al., 1997). Primary coalbed methane activity from the Ferron Sandstone takes place in the Drunkard's Wash

Unit (Figure A4-3). Total coal thickness in this area ranges from 4 to 48 feet (averaging 24 feet) from depths of 1,200 to 3,400 feet (Lamarre and Burns, 1996).

The Blackhawk Formation consists of coal interbedded with sandstone and a combination of shale and siltstone. The Blackhawk Formation is underlain by the Star Point Sandstone and overlain by the Castlegate Sandstone (Figure A4-2). The Castlegate Project in the Book Cliffs coal field (Figure A4-3) initially targeted coals in the Blackhawk Formation at depths ranging from 4,200 to 4,400 feet (Gloyn and Sommer, 1993).

4.2 Basin Hydrology and USDW Identification

Ground water hydrology of the Uinta Basin is controlled primarily by the geologic structure of the region (Howells et al., 1987). Variations of aquifer and aquitard permeablity owing to differences of lithology and facies changes also play an important role in the hydrology, as does widespread faulting and fracturing of the rocks (Howells et al., 1987). Because of the basin's structure, the area may be a ground water basin with internal drainage. If there were a deep ground water outlet for the basin, it would be along or near the axis of the Uinta Basin at its western edge. The general pattern of ground water flow is centripetal, with water flowing inward from recharge areas at exposures of permeable strata at the margins of the basin. Recharge is greatest near the northern edge of the basin. Other recharge areas include Eocene and Oligocene formations in the basin interior.

Most of the sandstone formations in the Mesozoic rocks in the Upper Colorado River Basin are identified as aquifers by the U.S. Geological Survey (Freethey and Cordy, 1991). They state that in the Uinta basin the older and deeper aquifers in strata below the Ferron Sandstone Member, (for example, the Navajo-Nugget aquifer, Entrada-Preuss aquifer, Morrison aquifer, and the Dakota aquifer) generally contain very saline to briny water, with TDS values greater than 10,000 mg/L. The Ferron Sandstone Member (Figure A4-4) is designated as a producing aquifer in east-central Utah (Freethey and Cordy, 1991). In regard to the Mesaverde Group aquifer, which includes the Star Point Sandstone, the Blackhawk Formation, the Castlegate Sandstone and the Price River Formation, (Figure A4-4) Freethey and Cordy (1991), state that, “water in these aquifers is more likely to be developed where the saturated thickness is large and the depth to the aquifer is less than 2,000 ft.” They further state that the margins of the Uinta basin where these rocks are near the surface or outcrop is a possible location for development of ground water with low enough TDS to be used for drinking water.

Wells in the Ferron Sandstone Member at the Drunkard's Wash coalbed methane field typically penetrate to depths of ranging from 1,200 to 3,400 feet (Lamarre and Burns, 1996). An average water quality value of 13,120 mg/L TDS (Gwynn, 1998) for production waters that have been retained in catchment ponds suggests that these wells are not within a USDW. Gwynn (1998) however, does state that due to the ponding of the produced water in evaporation lagoons, the concentration of salts in these waters has probably increased from their original levels. This implies that these water quality data may not be useful in the confirmation of USDW qualifications. Quarterly Review (1993) reported that three wells producing gas and water from the Ferron Sandstone Member coal beds in the Drunkards Wash field yielded over 49,000 gallons of water per day with a TDS of about 5,000 mg/L (sodium bicarbonate) during the first 2

to 3 months of operation. The Ferron Sandstone is hydrologically confined above and below by shale members of the Mancos Shale formation. Water produced from the Ferron Sandstone is thought to be connate water that was trapped in the sediment during coalification (Gloyn and Sommer, 1993). Hunt (Utah Division of Oil, Gas, and Mining, personal communication, 2001) noted that there were no USDWs located immediately above the Ferron Sandstone Member due to the thick tongues of Mancos Shale that encapsulate the coal bearing interval (Figure A4-2).

Production waters from coal beds in the Blackhawk Formation at the higher elevation Castlegate Field have TDS levels of about 5,000 mg/L (Methane From Coal Seams Technology, 1993), meeting the water quality criterion for a USDW. Beds targeted for methane gas exploration and production within the Blackhawk Formation are approximately 4,200 to 4,400 feet below the ground surface (Gloyn and Sommer, 1993), and TDS levels at those depths are about 5,000 mg/L TDS (Quarterly Review, 1993). Coalbed gas production in the Castlegate Field accounted for less than 10% of the coalbed methane production in the Uinta Basin (Petzet, 1996). The average gas well producing from the coal beds in the Blackhawk Formation (Castlegate field) yielded 318 barrels of water per day, and TDS levels of 5,489 mg/L have been measured in the produced waters (Gloyn and Sommer, 1993). In the western part of the Uinta Basin the Castlegate Sandstone, an aquifer, directly overlies the coal-bearing Blackhawk Formation (Figures A4-2 and A4-4) and hydraulic connection between the coals and the sandstone caused by fracturing might allow materials injected during fracturing to be transported from the coal beds to the sandstone. Similarly, fracturing and injection of development fluids might migrate downward from the target coal beds into the underlying Star Point Sandstone (Figures A4-2 and A4-4). Contamination below the Star Point Sandstone would probably be prevented by the underlying and relatively impermeable Upper Blue Gate Shale Member of the Mancos Shale. Contamination above the Castlegate Sandstone, similarly, would probably be prevented by the overlying and relatively impermeable shale and siltstone in the upper part of the Price River Formation and the overlying North Horn Formation.

In reference to the quality of water produced by the coalbed gas wells in both the Ferron Sandstone Member of the Mancos Shale and the Blackhawk Formation, Quarterly Review (1993) states: “Disposal of produced water does not appear to present a major environmental problem in the Uinta basin, unlike the San Juan and some other western basins. Rates are moderate, 200 to 300 barrels per day per well during early stages of production and TDS levels are not high (about 5,000 mg/L).” Because these TDS values are less than the 10,000 mg/L limit, the both the Ferron Sandstone Member of the Mancos Shale and the Blackhawk Formation may qualify as USDWs.

Tabet (Utah Geological Survey, personal communication, 2001) suggests that coalbed methane extraction wells are not located in "producing" aquifers and that most of the potable water in the sparsely populated area is supplied by surface water and shallow alluvial aquifers.

4.3 Coalbed Methane Production Activity

Exploration within the Uinta Basin began full-scale in the 1990s (Quarterly Review, 1993). The most active operators at that time were PG & E Resources Company, the River Gas Corporation, Cockrell Oil Corporation, and Anadarko Petroleum Corporation. PG&E acquired the Castlegate

Field, from Cockrell Oil (Gloyn and Sommer, 1993). Gas was produced from coal beds in the Blackhawk Formation. The five wells initially drilled in the Castlegate Field were hydraulically fractured with 80,000 to 143,000 pounds of sand and unreported volumes of fluid. Other wells were to be fractured with a low-residue gel system to ensure breakdown within the reservoir (Quarterly Review, 1993).

The Castlegate field is currently off-line (and has been for about two years) due to production water disposal problems; however, the field may be re-opened in the near future (Tabet, Utah Geological Survey, personal communication, 2001; and Hunt, Utah Division of Oil, Gas, and Mining, personal communication, 2001).

The River Gas Corporation operates the Drunkard's Wash Unit, producing methane gas from coals within the Ferron Sandstone Member. The company reported that high fracture gradients hampered hydraulic fracturing stimulations using cross-linked borate gel with 250,000 pounds of proppant (Quarterly Review, 1993). Excessive proppant flowback resulted in one well where nitrogen foam was used for the fracturing. The Buzzard Bench field, also producing gas from the Ferron Sandstone Member, was initially operated by Chandler & Associates, Inc (Petzet, 1996) and is currently being managed by Texaco (Garrison et al., 1997).

A query of a database covering the Uinta Basin revealed that there are about 1,255 coalbed methane wells in production in the basin (Osborne, USEPA Region VIII, personal communication, 2002). GTI places the annual coalbed methane production in the Uinta Basin at 75.7 billion cubic feet in 2000 (GTI, 2002).

4.4 Summary

Waters from coalbed methane production in the Ferron Sandstone Member of the Mancos Shale in the Drunkard's Wash Unit is conflictingly reported to have TDS values of about 13,000 mg/L or to have levels of TDS of about 5,000 mg/L. However, the higher values were derived from water samples taken from evaporation lagoons and these high values might represent elevated concentrations of salts owing to evaporation. Consequently, it is concluded that the more moderate TDS values are correct and thus the Ferron Sandstone Member would qualify as a USDW.

Ground water from the Blackhawk Formation within the Castlegate Field contains TDS concentrations below the USDW standard of 10,000 mg/L. Published TDS levels of 5,000 mg/L in production waters from the Castlegate Field coal beds in the Blackhawk Formation indicates that coalbed methane gas wells in this portion of the basin are developed in a USDW. The Blackhawk Formation and possibly the overlying Castlegate Sandstone in the Uinta basin qualify as USDWs.

The Drunkard's Wash and Castlegate coalbed methane extraction fields are located in a sparsely populated section of Utah. Tabet (Utah Geological Survey, personal communication, 2001) suggests that coal bed gas extraction wells are not located in "producing" aquifers and that most of the potable water in the sparsely populated area is supplied by surface water and shallow

alluvial aquifers. In this area of the Uinta Basin, there does not appear to be a conflict with coalbed methane extraction practices and water wells under present conditions.

It is unlikely that contamination is occurring in USDWs above or below the Ferron Sandstone Member due to the confinement of the coal bearing rocks beneath the Lower Blue Gate Shale Member and above the Tunuck Shale Member of the Mancos shale; both of these units have low permeabilities. On the other hand, the Blackhawk Formation is underlain by the Star Point Sandstone and overlain by the Castlegate Sandstone. Sandstones in these units can potentially serve as aquifers. Cross-contamination of these sandstone formations from hydraulic fracturing and coal bed gas development activities in the Blackhawk Formation is likely to be possible because contaminants would be able to migrate from the coals to the permeable sandstones.

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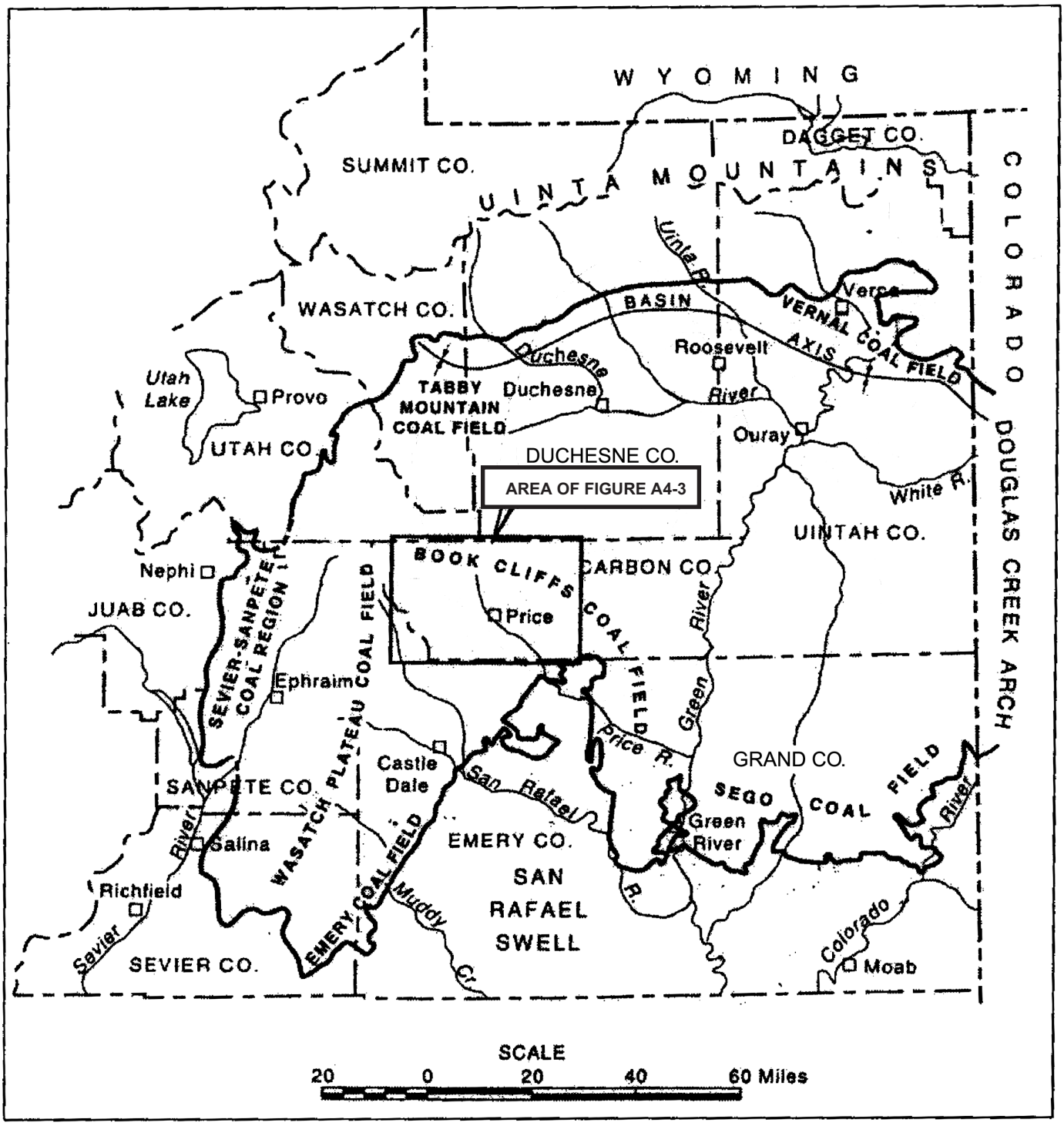
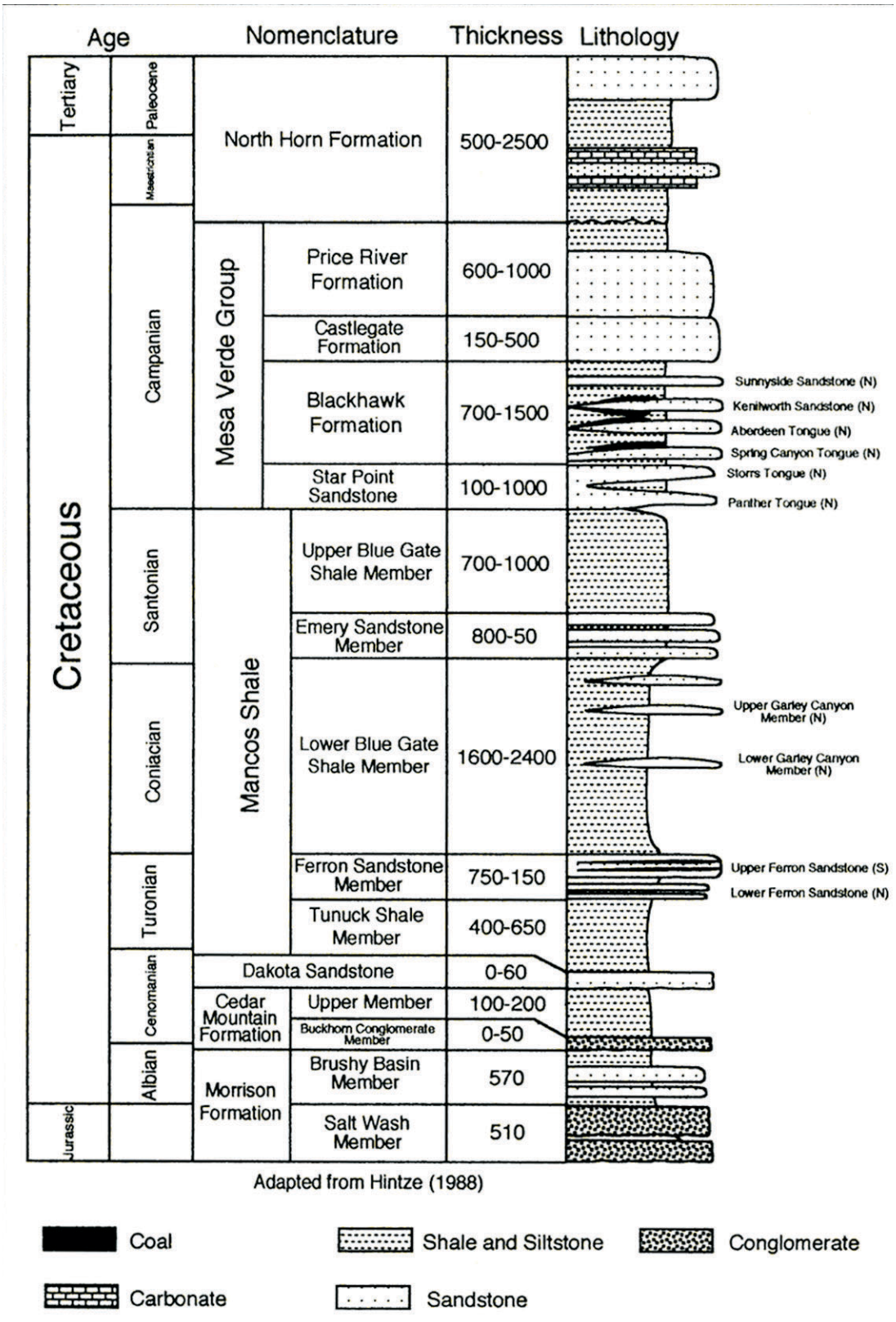


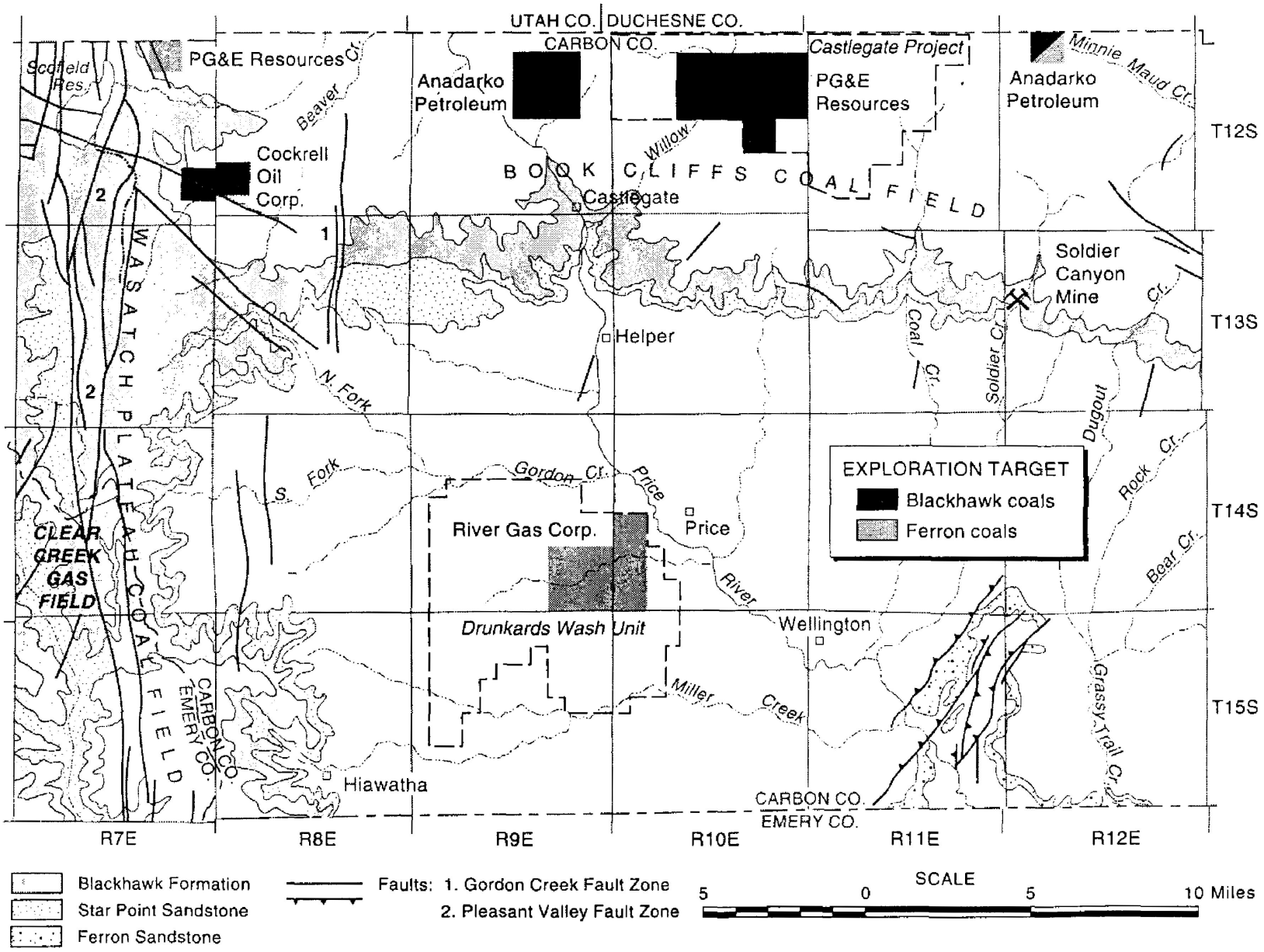
Index Map of Coal Fields in Uinta Basin, Utah (Quarterly Review, 1993)

7/14/01 kk 1027-HF-Uinta-1.cdr	Figure A4-1



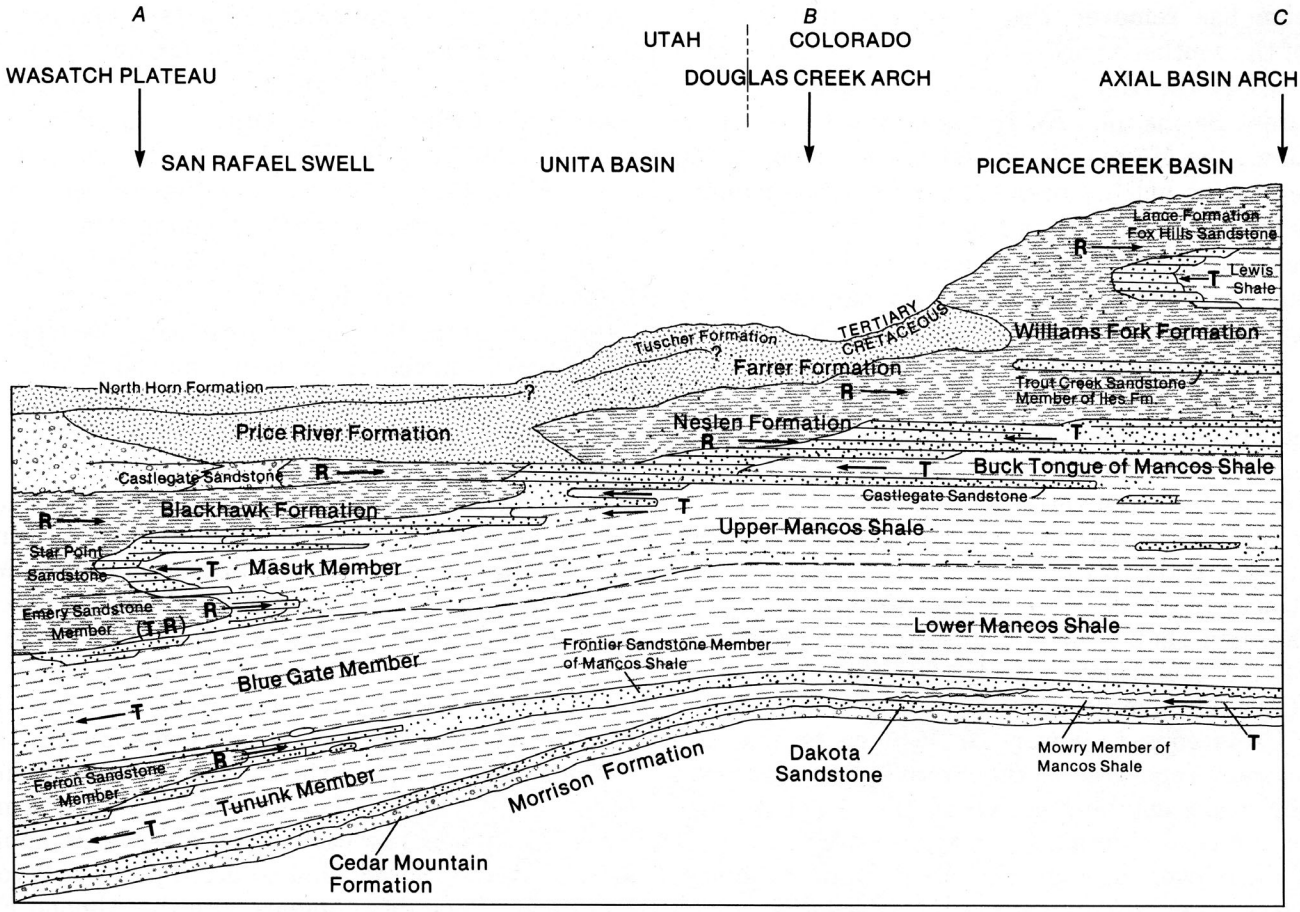
Stratigraphic Column for the Cretaceous of the Castle Valley (Garrison et al., 1997)

7/14/01 kk 1027-HF-Uinta-2.cdr	Figure A4-2



Coalbed Methane Development in Carbon County, Utah. (Methane from Coal Seams Technology, 1993)
Areas shown may not represent actual field, unit, or lease boundaries.

7/14/01 kk 1027-HF-Uinta-3.cdr	Figure A4-3



Horizontal distance not to scale

EXPLANATION

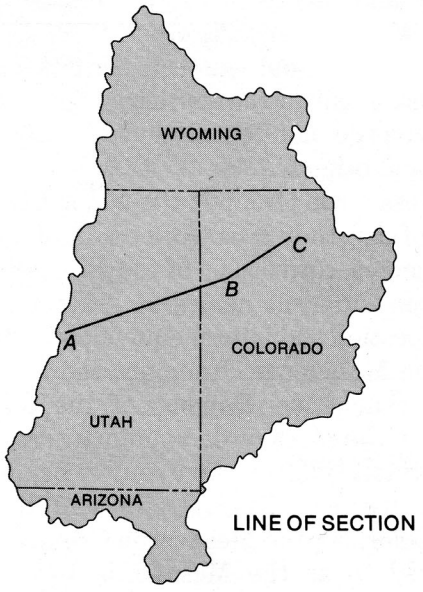
T = TRANSGRESSION

R = REGRESSION

← DIRECTION OF MOVEMENT OF SEAS

THICKNESS, IN FEET

4,000
3,000
2,000
1,000
0



Cross Section of Cretaceous Rocks (Freethey and Cordy, 1991)